Standalone Linear Li-Ion Battery Charger with Thermal Regulation

■ General Description

The XT4066 is a complete constant-current /constant -voltage linear charger for single cell lithium-ion batteries. Its ThinSOT package and low external component count make the XT4066 ideally suited for portable applications. Furthermore, the XT4066 is specifically designed to work within USB power specifications.

No external sense resistor is needed, and no blocking diode is required due to the internal MOSFET architecture. Thermal feedback regulates the charge current to limit the die temperature during high power operation or high ambient temperature. The charge voltage is fixed at 4.2V, and the charge current can be programmed externally with a single resistor. The XT4066 automatically terminates the charge cycle when the charge current drops to 1/10th the programmed value after the final float voltage is reached.

When the input supply (wall adapter or USB supply) is removed, the XT4066 automatically enters a low current state, dropping the battery drain current to less than 1μA. The XT4066 can be put into shutdown mode, reducing the supply current to 40μA.

When battery reversed,the internal protected the BAT pin throughout about 0.7mA current from GND.Also,The BAT pin has a 6KV ESD(HBM) capability.

Other features include charge current monitor, under-voltage lockout, automatic recharge and a status pin to indicate charge termination and the presence of an input voltage.

■ Features

- Programmable Charge Current Up to 1A
- No MOSFET, Sense Resistor or Blocking Diode Required
- Complete Linear Charger in small Package for single Cell Lithium-Ion Batteries
- Constant-Current/Constant-Voltage Operation with Thermal Regulation to Maximize Charge Rate Without Risk of Overheating
- Charges Single Cell Li-Ion Batteries Directly from USB Port
- Preset 4.2V Charge Voltage with ±1% Accuracy
- Charge Current Monitor Output for Gas Gauging
- Automatic Recharge
- Charge Status Output Pin
- C/10 Charge Termination
- 2.8V Trickle Charge Threshold
- Soft-Start Limits Inrush Current
- Battery reversed protection
- 6KV ESD(HBM) capability
- Available in ESOP8 Package

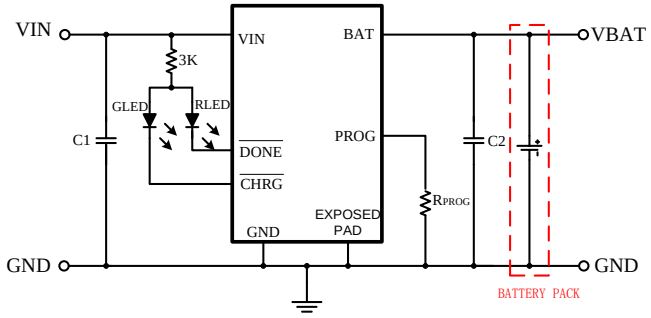
■ Applications

- Cellular Telephones, PDAs, MP3 Players
- Charging Docks and Cradles
- Bluetooth Applications

■ Package

- ESOP8

■ Typical Application Circuit



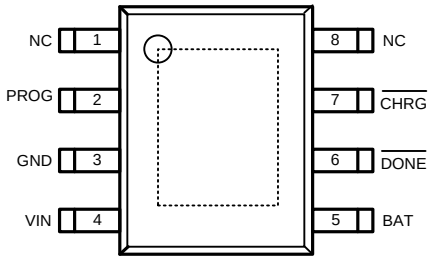
NOTE: C1=4.7μf, C2=4.7μF, IBAT = (V_{PROG}/R_{PROG})*1000

■ Ordering Information

XT4066 ①②③④⑤⑥

Designator	Description	Symbol	Description
①	Type	K	CHRG pin with trickle charge
②③	The regulator Output Voltage	42	4.2
④	Accuracy of Output Voltage	1	±1%
⑤	Packaging Types	S	ESOP8
⑥	Device Orientation	R	Embossed tape: Standard feed
		L	Embossed tape: Reverse feed

■ Pin Configuration



ESOP8
(TOP VIEW)

■ Pin Assignment

Pin Number ESOP8	Pin Name
1	NC
2	PROG
3	GND
4	VIN
5	BAT
6	$\overline{\text{DONE}}$
7	$\overline{\text{CHRG}}$
8	NC

■ Pin Function

NC (Pin 1 and Pin 8): No Connected.

PROG (Pin 2): Charge Current Program, Charge Current Monitor and Shutdown Pin. The charge current is programmed by connecting a 1% resistor, R_{PROG}, to ground. When charging in constant-current mode, this pin servos to 1V. In all modes, the voltage on this pin can be used to measure the charge current using the following formula:

$$IBAT = (V_{PROG}/R_{PROG}) \bullet 1000$$

The PROG pin can also be used to shut down the charger. Disconnecting the program resistor from ground allows a 3μA current to pull the PROG pin high. When it reaches the 1.21V shutdown threshold voltage, the charger enters shutdown mode, charging stops and the input supply current drops to 40μA. This pin is also clamped to approximately 2.4V. Driving this pin to

voltages beyond the clamp voltage will draw currents as high as 1.5mA. Reconnecting RPROG to ground will return the charger to normal operation.

GND (Pin 3): Ground.

VIN (Pin 4): Positive Input Supply Voltage. Provides power to the charger. VIN can range from 4.25V to 6.5V and should be bypassed with at least a 1μF capacitor. When VIN drops to within 100mV of the BAT pin voltage, the XT4066 enters shutdown mode, dropping IBAT to less than 2μA.

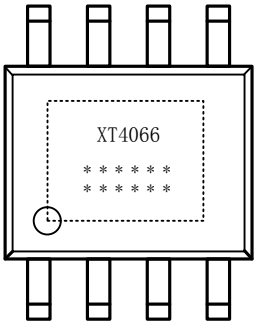
BAT (Pin 5): Charge Current Output. Provides charge current to the battery and regulates the final float voltage to 4.2V. An internal precision resistor divider from this pin sets the float voltage which is disconnected in shutdown mode. When the battery reverse, the internal protection circuitry protect the chip will not be burned. And about 0.7mA current flows from GND to BAT.

DONE (Pin6): Full indication output, when fully charged, DONE port is an internal P-channel MOSFET placed in high position. In the charging process, low-power lock condition is detected, the input is too high to detect locking conditions, DONE is forced high impedance.

CHRG (Pin 7): Open-Drain Charge Status Output. When the battery is charging, the CHRG pin is pulled low by an internal N-channel MOSFET. When the charge cycle is completed or the XT4066 detects an undervoltage lockout condition, CHRG is forced high impedance.

■ Marking Rule

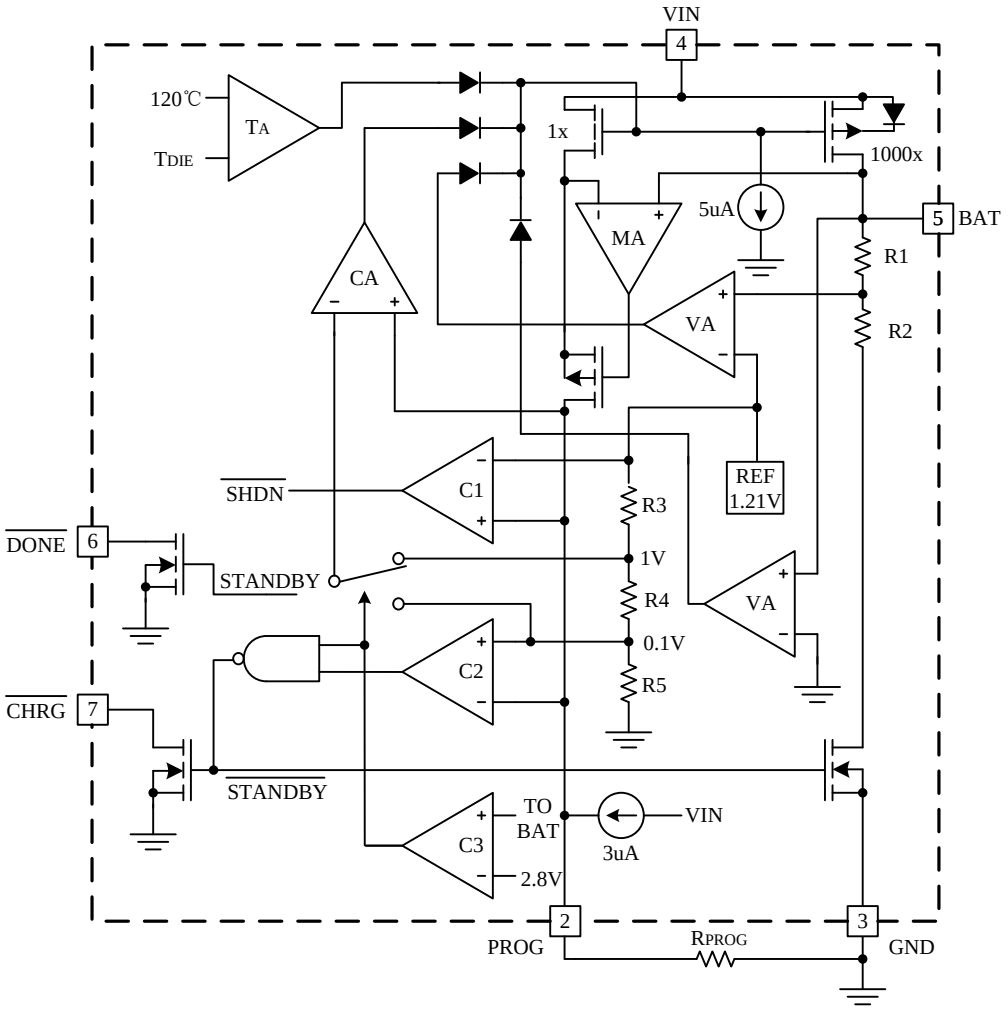
- **ESOP8**



ESOP8
(TOP VIEW)

********: Represents the information about product quality tracking.**

■ Block Diagram



■ Absolute Maximum Ratings

Parameter	Symbol	Maximum Rating	Unit
Input Supply Voltage	V_{IN}	V_{SS}-0.3～V_{SS}+12	V
PROG pin Voltage	Vprog	V_{SS}-0.3～VIN+0.3	
BAT pin Voltage	Vbat	Vss-0.3～12	
CHAG, DONE pin Voltage	Vchrg	V_{SS}-0.3～V_{SS}+12	
Power Dissipation	P_D	1000	mW
BAT pin Current	Ibat	1500	mA
PROG pin Current	Iprog	1500	uA
Operating Ambient Temperature	Topa	-40～+85	°C
Storage Temperature	Tstr	-65～+125	

Caution: The absolute maximum ratings are rated values exceeding which the product could suffer physical damage. These values must therefore not be exceeded under any conditions.

■ Electrical Characteristics

(TA=25℃ unless otherwise noted)

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Input supply voltage	VIN	-	4.25	-	6.5	V
Input supply current	Icc	Charge mode,Rprog=10K	-	200	400	μA
		Standby mode	-	100	200	μA
		Shutdown mode(Rprog not connected,VIN<Vbat or VIN<Vuv)	-	40	100	μA
Regulated Output Voltage	Vfloat	0℃<TA<85℃, IBAT = 40mA	4.16	4.2	4.25	V
BAT pin Current	Ibat	Rprog=10k,Current mode	93	100	107	mA
		Rprog=2k,Current mode	465	500	535	mA
		Standby mode,Vbat=4.2V	0	-2.5	-6	μA
		Shutdown mode	-	1	2	μA
		Battery reverse mode, VBAT=-4V	-	0.7	-	mA
		Sleep mode,VIN=0V	-	1	2	μA
Trickle charge current	Itrikl	Vbat<Vtrikl,Rprog=2k	93	100	107	mA
Trickle charge Threshold Voltage	Vtrikl	Rprog=10K，Vbat Rising	2.7	2.8	2.9	V
Trickle voltage hysteresis voltage	Vtrhys	Rporg=10k	50	75	100	mV
VIN Undervoltage lockout Threshold	Vuv	From VIN low to high	3.7	3.8	3.93	V
VIN undervoltage lockout hysteresis	Vuvhys		80	100	120	mV
Manual shutdown threshold voltage	Vmsd	PROG pin rising	1.15	1.21	1.30	V
		PROG pin falling	0.9	1.0	1.1	V
VIN-Vbat Lockout Threshold voltage	Vasd	VIN from low to high	160	210	260	mV
		VIN from high to low	70	100	130	mV
C/10 Termination Current Threshold	Iterm	Rprog=10k	0.085	0.10	0.115	mA/mA
		Rprog=2k	0.085	0.10	0.115	mA/mA
PROG pin Voltage	Vprog	Rprog=10k, Current mode	0.93	1.0	1.07	V
CHRG pin weak pull-down Current	Ichrg	Vchrg=5V	8	20	35	μA
CHRG pin Output low voltage	Vchrg	Ichrg=5mA	-	0.35	0.6	V
Recharge Battery threshold Voltage	ΔVrecg	VFLOAT - VRECHRG	50	100	150	mV

■ Application Information

- **Set the charge current**

In constant-current mode, formula for calculating charge current: I_{PROG} = 1000V / R_{PROG}.

H represents the charges current, units are ampere, R_{PROG} represents PROG pin to ground resistance in ohms. For example, if you need 500 mA charges current, according to the following formula: R_{PROG} = 1000V/0.5A = 2KΩ

In order to ensure good stability and temperature characteristics, R_{PROG} recommend the use of 1% precision metal film resistors. By measuring the PROG pin voltage can be detected charge current. Charge current can be calculated using the following formula: $I_{CH} = (V_{PROG} / R_{PROG}) \times 1000$

- **Application of USB and AC adapter while charging at the same time**

XT4066 can not only use USB interface to charge the battery, users can also use a wall adapter to charge the battery. Figure 1 shows a same time using the USB interface and the AC adapter to charge the battery through the XT4066 .when the two co-exist, the AC adapter has priority. M1 is the P-channel MOSFET, M1 is used to prevent current from a wall adapter into the USB interface, USB interface, Scotty diode D1 prevents the consumption of energy through the 1K resistor.

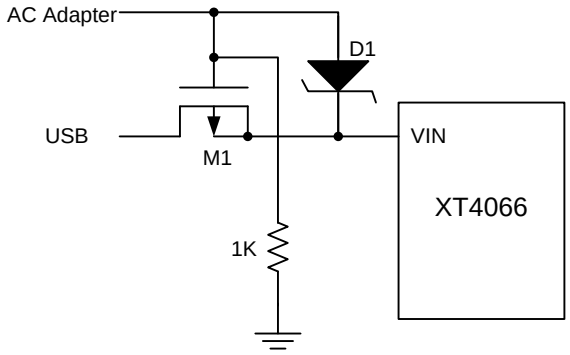


Figure1. While using the AC adapter and USB interfaces

- **Battery temperature monitoring**

In order to prevent the battery temperature is too high or too low, the damage caused by the battery, the XT4066 internal integrated battery temperature monitoring circuit.

- **Enable design**

By controlling whether the PROG pin resistor connected, users can reach close XT4066 function. Figure 2:

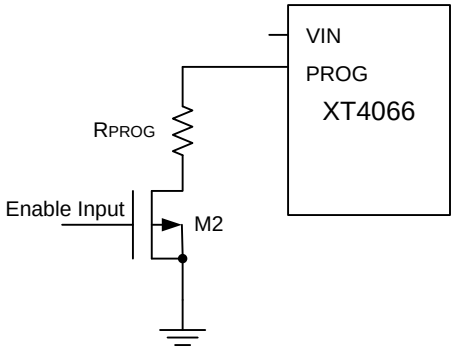


Figure 2

- **Open-drain output status indication**

XT4066 has two open-drain status indication sides, CHRG and DONE, the two status indicator LEDs client can drive or microcontroller port. CHRG used to indicate charging status, charging time, CHRG is low; DONE to indicate the charging end of the state, when the charging end, DONE is low. When the battery temperature is outside the normal temperature range more than 0.15 seconds, CHRG and the DONE pin is high impedance output state.

When the battery charger not received, the charger will quickly charge the output capacitor to the constant voltage value, as the battery voltage detection the BAT pin input leakage current, the BAT pin voltage will slowly down to recharge threshold, so the BAT pin voltage is 150mv to form a ripple waveform, while CHRG output pulse signal that there is no battery installed. When the battery BAT pin external connectors for the 4.7uF capacitor and no load been connected, the pulse period of about 2Hz.

The following table lists CHRG and DONE pin status in each case：

State	Charge	Full	Without Battery	Error
CHRG	Always bright	Always off	Flashing	Always off
DONE	Always off	Always bright	Always bright	Always off

Note: 1. CHRG flicker frequency with external capacitor when not connect battery, generally recommended 4.7uF.The greater the capacitance, the smaller frequency flicker.

2. The error situation: Beyond the operating temperature range (temperature too high or too low), PROG side vacant, Vin <Vbat, Vin <3.8V and so on.

- **The large current output design**

Since the XT4066 using the internal constant power technology, therefore , when the input VIN and BAT pressure is too large , will lead to smaller the BAT voltage range of the maximum current , so that the charging time becomes longer , in order to make the maximum current charging interval larger by an external resistor or Schottky methods to achieve.

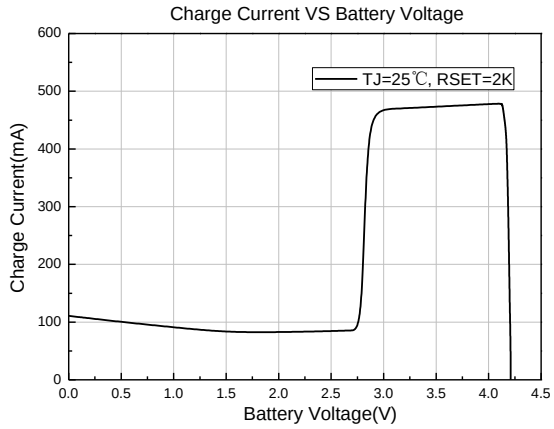
The assumption the XT4066 of ESOP8 inside the package the maximum allowable power 1.2W, maximum charge current is set to 1.2A. If uses a resistive, We assume that the use of the resistance of 0.5Ω (1W), High current charging, the voltage drop across the resistor is 0.5*1.2=0.6V. The XT4066 real operating voltage is 4.4V. Thus, in this state, (VIN-VBAT) *1.2<1.2W, therefore VBAT>3.6V，The battery voltage is above 3.6V 1.2A charging support. Below 3.6V, the XT4066 will automatically reduce the charge current to maintain the chip internal power balance.

If Schottky similar calculation can be made, according to the Schottky voltage drop at different current .

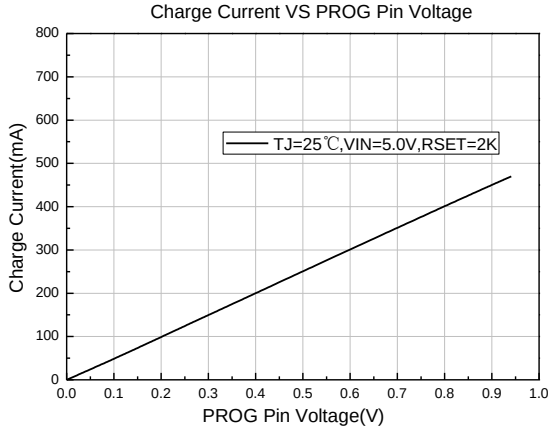
In addition, in the high-current applications need to pay attention XT4066 PCB layout design must consider increasing EXPOSED PAD area, and will be connected to the EXPOSED PAD to GND in order to improve the thermal performance, and ensure the stable operation of the chip.

■ Typical Performance Characteristics

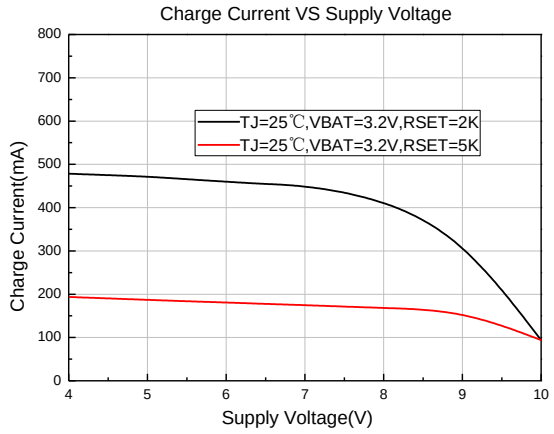
1. Charge Current VS Battery Voltage



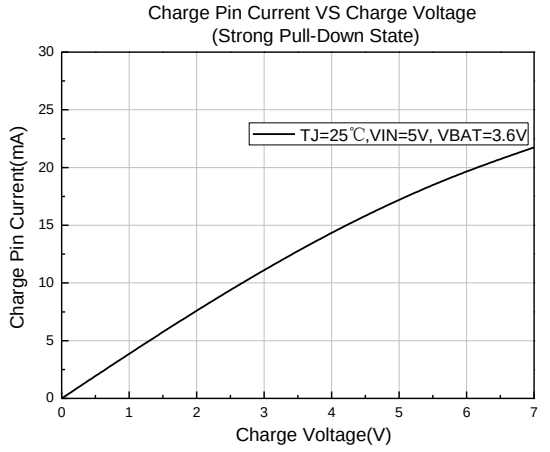
2. Charge Current VS PROG Pin Voltage



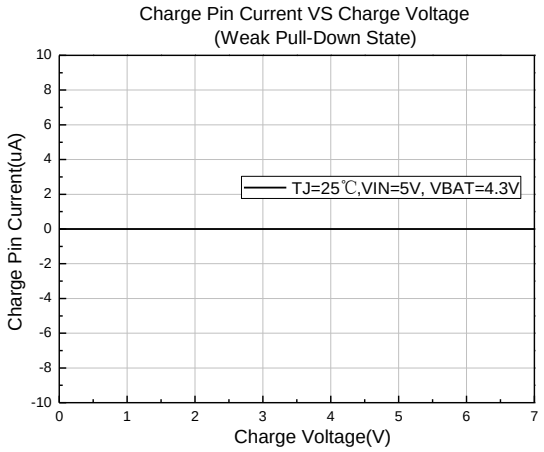
3. Charge Current VS Supply Voltage



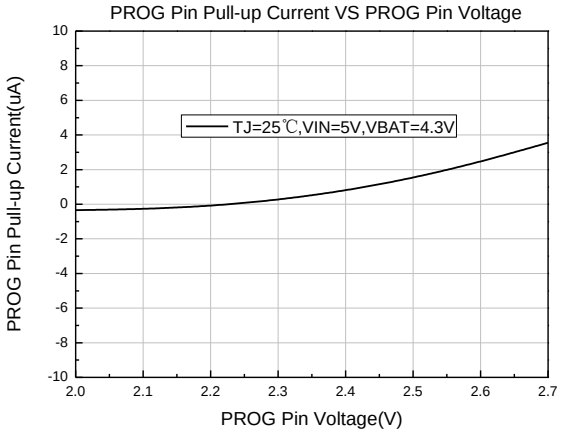
4. Charge Pin Current VS Charge Voltage (Weak Pull-Down State)



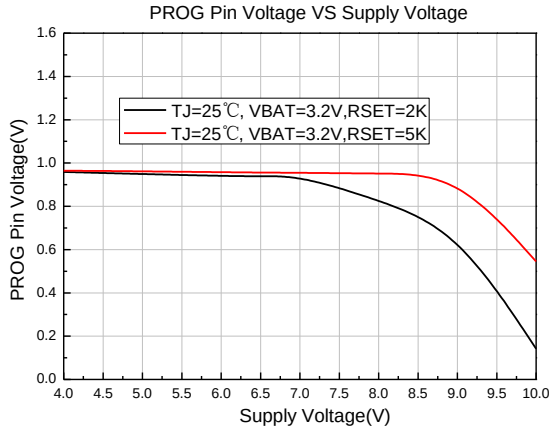
5. Charge Pin Current VS Charge Voltage (Weak Pull-Down State)



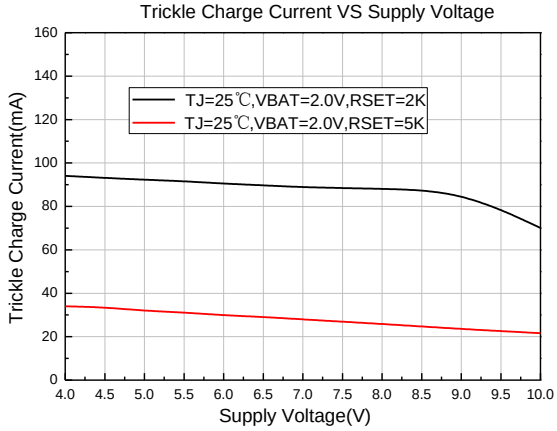
6. PROG Pin Pull-up Current VS PROG Pin Voltage



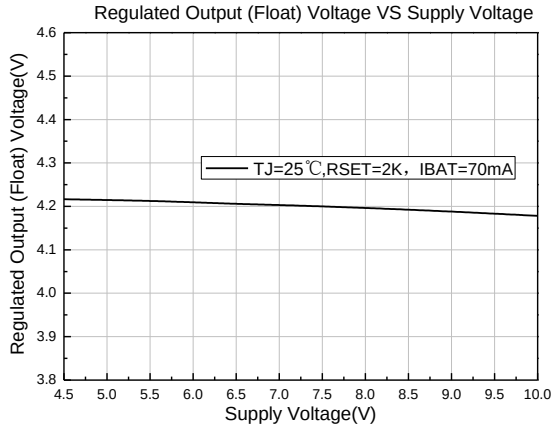
7. PROG Pin Voltage VS Supply Voltage



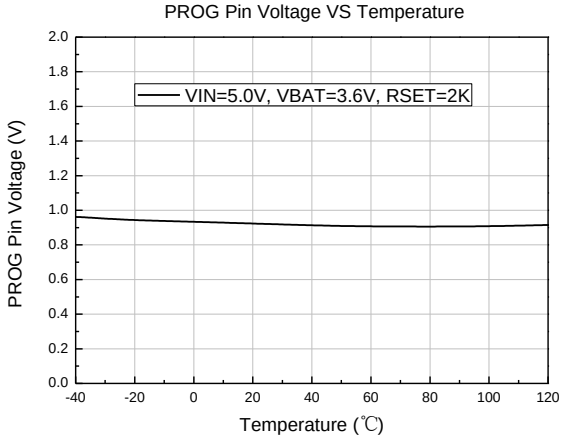
8. Trickle Charge Current VS Supply Voltage



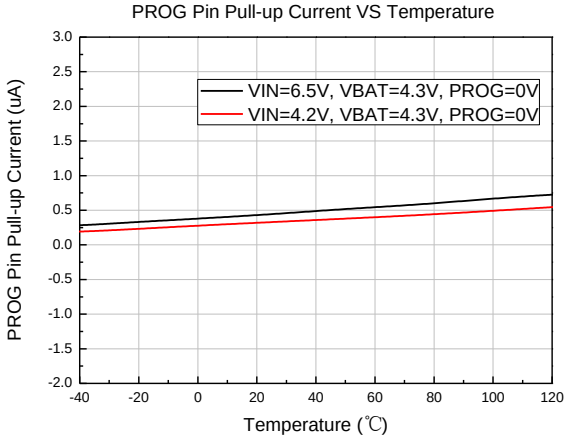
9. VBAT VS Supply Voltage



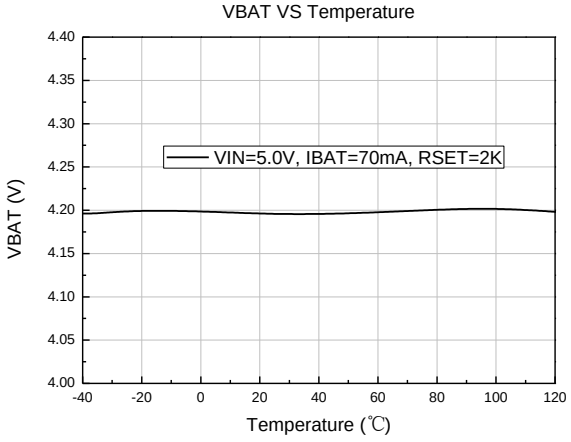
10. PROG Pin Voltage VS Temperature



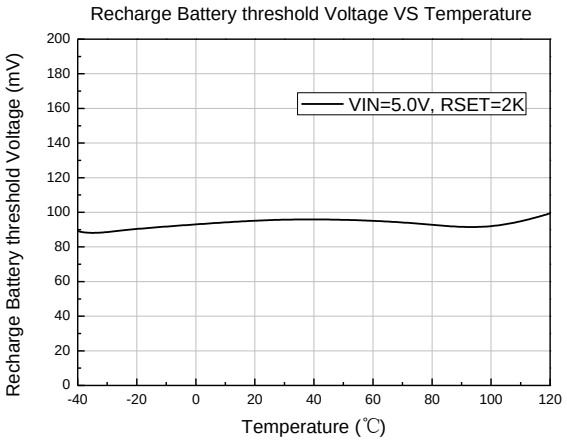
11. PROG Pin Pull-up Current VS Temperature



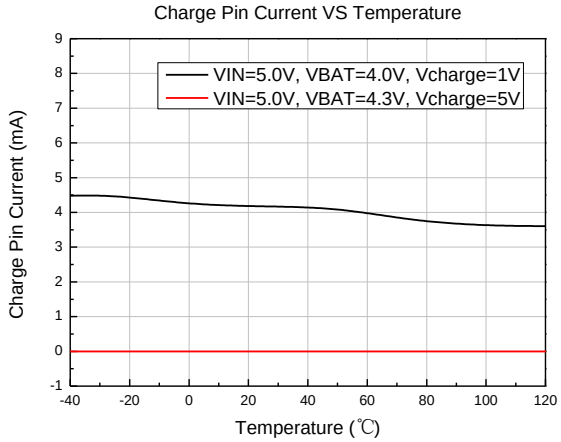
12. BAT VS Temperature



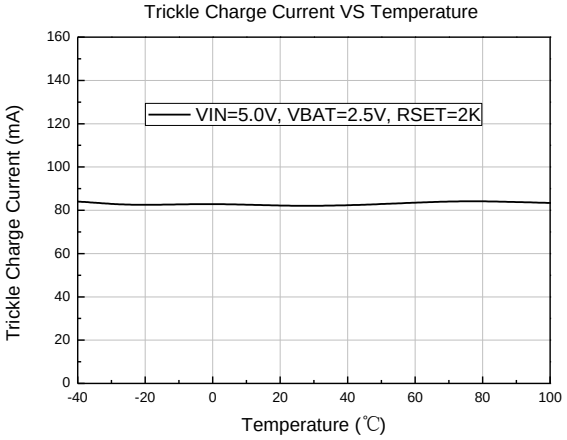
13. Recharge Batter threshold Voltage VS Temperature



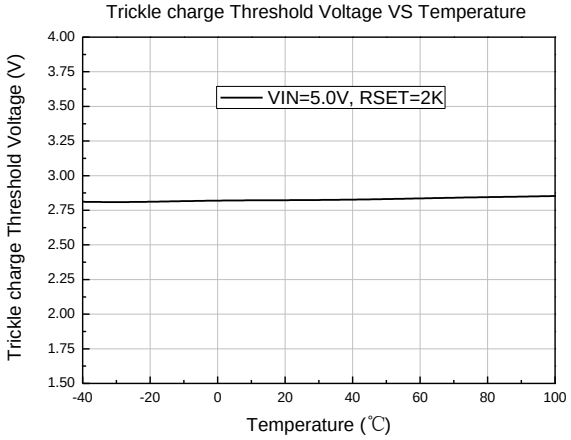
14. $\overline{CHRG}$ Pin Current VS Temperature



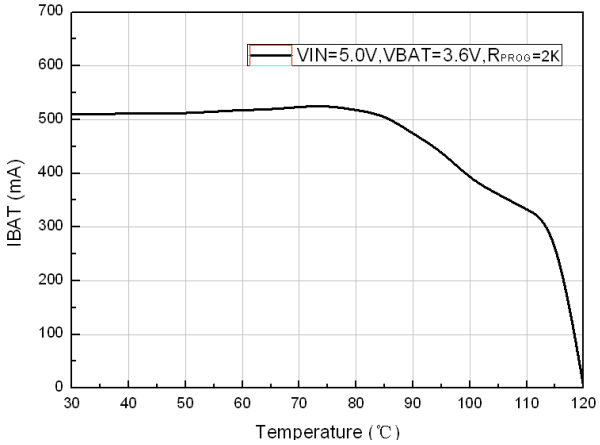
15. Trickle Charge Current VS Terperature



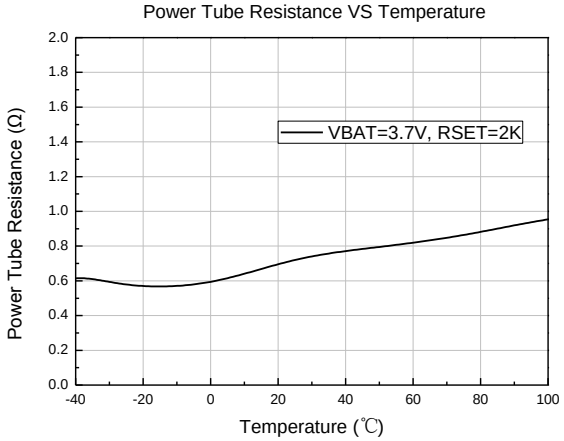
16. Trickle Charge Threshold Voltage VS Temperature



17. IBAT VS Temperature

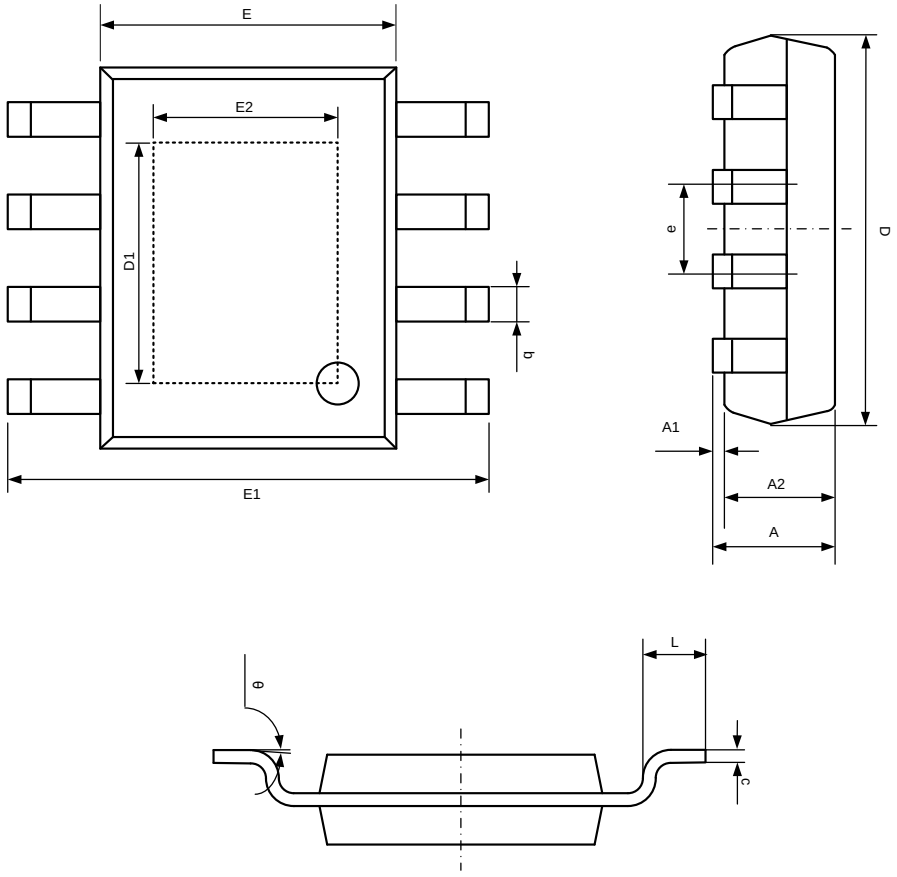


18. Power MOS on Resistance VS Temperature



■ Package Information

- **ESOP8**



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.050	0.150	0.002	0.006
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.200
D1	3.202	3.420	0.126	0.134
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
E2	2.313	2.513	0.091	0.099
e	1.270(BSC)		0.050(BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°